

APPLICATION FOR UNITED STATES LETTERS PATENT  
FOR  
STEPPED POLYCRYSTALLINE DIAMOND COMPACT INSERT  
BY  
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## FIELD OF THE INVENTION

[0001] The present invention relates generally to earth boring drill bits, and in particular to a polycrystalline diamond compact (PDC) insert exhibiting a stepped profile structure for use in a fixed cutter earth boring bit or reamer.

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## BACKGROUND OF THE INVENTION

[0002] PDC inserts are commonly used to increase the wear resistance of surfaces in certain types of down hole tools. For example, inserts on a reamer, in association with a drill bit, are used on outer blade surfaces to resist wear from the bore hole wall. The reamer enlarges the bore hole to a diameter than that created by the drill bit.

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[0003] The function of the reamer is to maintain the diameter of the hole as the drill bit proceeds downwardly through the rock formation. As the bore hole is being drilled, the rock drill bit gradually wears to undersize and thus the hole which is cut gradually becomes of undersize diameter. The function of the reamer, which typically has PDC inserts along the outer blade edge, is to grind the circumference of the hole, shortly after it has been cut by the rock drill bit, and thus keep the hole diameter to size.

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[0004] Inserts are also commonly used in fixed cutter drill bits along a cutting blade which is stationary in respect of the drill string, in contrast to roller cone bits. Such a fixed cutter drill bit typically has a leading face from which a plurality of blades extend, each blade carrying a plurality of cutting elements comprising PDC inserts. Inserts may also be placed along a gauge pad at the extreme outer diameter of each blade.

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[0005] PDC inserts have a polycrystalline diamond surface formed on wear surfaces, which may be formed in a variety of ways, principally in a conventional process under heat and pressure, or by sintering. The inserts are formed of a tungsten carbide material, and the wear surface is then applied. In the past, such inserts commonly have had a flat or slightly ovoid outer contact region, where the insert contacts the rock formation being cut. Regardless of the configurations of the inserts, they have all had a characteristic in

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common, and that is the inserts define one point, line, or area contact with the rock formation. As the rock formation increases in hardness, the resistance or "work load" necessary to disintegrate the formation at that area also increases. The increased resistance causes two common problems. The increased resistance on individual inserts can cause premature chipping or breakage failure of the inserts. Also, the combined increase of resistance on all the PDC inserts increases the amount of torque required to drive the bit and causes the bit to stop momentarily while drilling, a condition known as "stick slip" drilling. There is a present need in this art for PDC inserts that can drill harder formations with less risk of failure and with less risk of "stick slip". The present invention is directed to this need in the art.

#### SUMMARY OF THE INVENTION

[0006] The present invention addresses both of these noted problems in the art by providing a PDC insert comprising a plug section and a pedestal section. The cutter insert is preferably formed of tungsten carbide, except for two exterior surfaces covered with PDC. The plug section may be circular or oval in cross section perpendicular to the axis of the insert. The plug section and the pedestal each defines a shoulder which is coated with a PDC layer. In one preferred embodiment of the invention, the pedestal section provides a second smaller cutting area or edge which precedes the cutting area of the plug. This leading cutting edge cuts a narrow groove in the formation just ahead of the larger plug cutting area. This narrow groove reduces the rock strength of the formation cut by the plug surface and obviously reduces the amount of rock cut by the plug surface. Dividing the work load over two edges reduces the load per edge resulting in less risk of PDC failure.

[0007] In another preferred embodiment, the pedestal section is designed to limit the depth that the plug edge can embed into the rock formation. As additional weight is applied to a PDC bit during normal operation, the PDC inserts are forced to embed deeper into the formation. As the inserts embed deeper, work load is increased and this results in more torque being required to turn the bit. As previously described, at some point, the

torque reaches a level causing a "stick slip" drilling condition. "Stick slip" drilling is very detrimental to PDC bits often resulting in premature failure of the bits.

5 [0008] The deeper embedding of the insert into the formation also causes many other problems with the drill string and rig. The pedestal of the present invention is designed to slide across the formation rather than embed and cut the formation. This action limits the depth which the plug edge can embed into the formation. In the additional embodiment of the invention, the amount of embedding of the plug edge remains about the same even as the WOB (weight on bit) is increased substantially. Limiting the amount of embedding of the inserts limits the amount of torque required to rotate the bit and reduces the risk of  
10 "stick slip" drilling and all the problems associated with it.

[0009] Thus, the present invention is directed to improving PDC drilling in harder formations. These and other features and advantages of this invention will be readily apparent to those skilled in the art.

## 15 BRIEF DESCRIPTION OF THE DRAWINGS

[0010] So that the manner in which the above recited features, advantages and objects of the present invention are attained and can be understood in detail, more particular description of the invention, briefly summarized above, may be had by reference to embodiments thereof which are illustrated in the appended drawings.

20 [0011] Figure 1 is a perspective view of a fixed cutter bit wherein the PDC insert of the present invention finds application.

[0011] Figure 2 is an elevation view of reamer on a rotary cone drill bit wherein the PDC insert of the present invention finds application.

25 [0012] Figure 3 is a perspective view of a presently preferred embodiment of a PDC insert of the invention.

[0013] Figure 4 is a perspective view of another presently preferred embodiment of a

PDC insert of the invention.

[0014] Figure 5 is a side section view of a PDC insert of the invention as it cuts into a formation.

5 [0015] Figure 6a is a side view of a PDC insert of this invention which limits the depth of the cut of the plug.

[0016] Figure 6b is a side view of another PDC insert which further limits the depth of the cut of the plug.

[0017] Figure 6c is a side view in partial section, illustrating the depth limiting aspect of this embodiment of the invention.

#### 10 DETAILED DESCRIPTION OF A PREFERRED EMBODIMENT

[0018] Figure 1 shows a fixed cutter drill bit 10 including inserts 12 of the present invention. The drill bit 10 has a central axis of rotation 12 and a bit body 14 having a leading face 16, an end face 18, a gauge region 20, and a shank 22 for connection to a drill string (not shown). A plurality of blades 26 extend from the leading face 16 of the bit body away from the central axis of rotation 12 of the bit 10. Each blade 26 terminates in a gauge pad 28 having a gauge surface 29 which faces a wall 30 of a borehole (not shown).

15 [0019] A number of cutter inserts 12 are mounted on the blades 26 at the end face 18 of the bit 10 in both a cone region 36 and a shoulder region 38 of the end face 18. Each cutter 12 partially protrudes from its respective blade 26 and the cutter inserts are spaced apart along the blade 26, typically in a given manner to produce a particular type of cutting pattern. The structure of the cutter insert of the invention is shown in greater detail in Figures 3, 4, and 5, below.

20 [0020] The cutter insert of the invention also may find application in a reamer 44 as shown in the reaming assembly 40 shown in Figure 2. The reamer 44 follows a roller

cone bit 42 of conventional design and a reamer section 44. The roller cone bit 42 may be joined to the reamer section 44 with a threaded connection 46 and another threaded connection 48 is provided to join the reamer section to a drill string (not shown). The reamer section includes a plurality of blades 50 and each blade includes a plurality of cutter inserts 52, constructed in accordance with the teachings of this invention, as will now be described.

[0021] Figures 3, 4, and 5 illustrate the cutter insert of the invention. Figure 3 shows a cutter insert 60 comprising a plug section 62 and a cutter pedestal 64. The cutter insert 60 is preferably formed of tungsten carbide, except for two exterior surfaces covered with PDC. The plug section, which in Figure 3 is circular in cross section perpendicular to the axis of the insert, defines a shoulder 66 which is coated with a PDC layer extending part way onto a step or shelf 68. Also, the cutter pedestal section 64 is covered with a PDC layer, which extends part way down onto a slanted wall 70. Thus, the pedestal section also defines a pedestal shoulder 72, covered with PDC. The wall 70 may be slanted to provide a tapered profile for the pedestal section, thereby providing a stronger base for a top surface 74. The plug shoulder 66 and the pedestal shoulder 72 define two distinct cutting surfaces for the cutter insert 60.

[0022] Figure 4 shows another preferred embodiment of a cutter insert 80, which is similar in most respects to the insert illustrated in Figure 3, except that a pedestal 82 has an oval cross section when taken perpendicular to the axis of the cutter segment. The insert 80 is modestly more expensive to manufacture, but provides the advantage of allowing a pedestal shoulder 84 to cut a narrow, deep leading groove through rock. The geometry of the insert 80 places less work load on the top which initiates the groove, and places more on the lower cutting surface which scrapes away less supported formation on the sides of the initial groove.

[0023] Figure 5 shows how the cutter insert works. A cutter insert 90, constructed as just described, is inserted into a hole 92 in a body 94, preferably a blade in a fixed cutter of Figure 1 or a reamer of Figure 2. The shoulders 66 and 72 of the cutter 60 engage the formation at two points. Thus, as the cutter moves across the face of the formation in a

direction 96, more material may be worn or chipped away, increasing the speed of the cutter through the formation.

5 [0024] Figures 6a, 6b, and 6c show another preferred embodiment of the invention, in which the degree of embedding into a formation 100 is limited in order to alleviate the problem of stick slip, and the maintain a more constant torque on the bit while drilling in hard formations. In the embodiment of Figure 6a, an insert 101 comprises a plug 102 integrally formed with a pedestal 104, in a manner previously described. A fillet 106 joins the pedestal to the plug to reduce stress cracking at the joint. Then, in ascending order, the pedestal defines a vertical surface 108, a first convex curved surface 110, a straight, frustoconical bevel surface 112, a second convex curved surface 114, and a flat top 116. The bevel surface 112 preferably forms an angle  $\beta$  with an axis 118 of the insert 101, as shown in Figure 6c. The bevel angle  $\beta$  is also approximately equal to a insert back rake angle  $\alpha$ , so that the pedestal tends to ride along the surface of the formation 100, rather than digging into it.

15 [0025] Another embodiment which limits the depth of cut is shown in Figure 6b. An insert 120 includes a plug 122 and a pedestal 124. The pedestal 124 defines a circular flat top 125 and a substantially vertical or cylindrical wall 126 in which is formed a large, flat bevel 128. Viewed another way, the bevel 128 defines a surface which cuts across the flat top, thereby forming a chord across the top. The bevel rides against the formation, rather than cutting into it. Thus, as the weight on bit increases, the bevel keeps the insert from digging down into the formation, maintaining a fairly constant torque and reducing the likelihood of stick slip.

25 [0026] The principles, preferred embodiment, and mode of operation of the present invention have been described in the foregoing specification. This invention is not to be construed as limited to the particular forms disclosed, since these are regarded as illustrative rather than restrictive. Moreover, variations and changes may be made by those skilled in the art without departing from the spirit of the invention.